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Proposal Number:	05-NE-325
Research Title:	(DURIP FY06) DEVELOPMENT OF THZ FIBER LASERS
Type Submission:	~~New Work Effort~~ Final Report
Inst. Control Number:	FA9550-06-1-0390DEF
Institution:	RENSSELAER POLYTECHNIC INSTITUTE
Primary Investigator:	Dr. Xi Cheng Zhang
Invention Ind:	none
Project/Task:	5094U / S
Program Manager:	Gernot S. Pomrenke

Objective:

This program supports the acquisition of equipment to develop a new high power, narrow band terahertz (THz) source. The aim is to develop a THz fiber laser based on a THz lasing mechanism and a novel photonic crystal fiber technique. The envisioned equipments, including a tunable CO2 laser, power meters and spectrometers in mid-infrared and far-infrared range, photonic bandgap fibers and coupling optics, will be used to design, build and test the THz fiber laser.

Approach:

The effort will focus on developing a terahertz laser using photonic crystal fibers. The methanol laser pumped by CO2 will be explored as the lasing mechanism. In order to develop the THz fiber laser, the following equipment will be purchased: a CO2 laser, photonic bandgap fibers, coupling devices and optics for the fibers, power meters and spectrometers. A tunable CO2 laser with a tunable range of 9-11 micrometer and a maximum output power of 100W is necessary to pump the Methanol vapor to generate the radiation in THz range. The photonic bandgap fiber in THz range will be designed and produced specifically for this spectral regime. The lock in amplifier, the translation stage and the motion controller are used to build a THz spectroscopy system for measurement of THz radiation. The THz power meter is used for the measurement of the THz output and alignment of the system.

Progress:

Year: 2007 **Month:** 09 **Final**

There is no Current commercially available THz fiber Laser on the market, and there is no any report successful demonstration of THz fiber lasers in literatures. Our DURIP project is to develop a THz fiber Las¿ on a novel photonic crystal fiber technique. The THz fiber laser has several important characteristics; sm portability, room temperature operation, and high output power. ALL provide advantages over current THz La a new high-power, narrow-band THz source, the THz fiber laser has potential applications in the r communication, and security and defense industries.

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14. ABSTRACT
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15. SUBJECT TERMS

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Final Performance Report for Development of THz Fiber Laser

Award No.: FA9550-06-1-0390

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1. Project Goal

There is no current commercially available THz fiber laser on the market, and there is no any report on the successful demonstration of THz fiber lasers in literatures. Our DURIP project is to develop a THz fiber laser based on a novel photonic crystal fiber technique. The THz fiber laser has several important characteristics; small size, portability, room temperature operation, and high output power. All provide advantages over current THz lasers. As a new high-power, narrow-band THz source, the THz fiber laser has potential applications in the medical, communication, and security and defense industries.

2. Progress

Within the DURIP project, we have successfully purchased laser components and constructed first and second version THz fiber laser cavities.

The achievements of the project are:

- Purchase of CO_2 laser components.
- Completion of first cavity.
- Completion of second cavity.

Coherent[1], manufacturer of the THz gas laser, provided guidance on how to build the laser cavity in which the fiber could be place within the tube. The recommendations that we got were to build a straight cavity with two mirrors at the extremes of a fiber holder and put the assembly into an environment of low-pressure methanol vapor. The recommended length of the cavity is in the range of a meter or so. To couple the radiation in and out, Coherent suggested drilling a 2 mm diameter hole in each mirror. The CO_2 beam will have to be focused tightly to go through the hole, while the THz

[1] Coherent. Available: http://www.coherent.com/

radiation will exit the other hole. Following Coherent's recommendation, we have built two cavities using an extruded aluminum profile for the basic building block of THz fiber lasers.

At the end of the DURIP project (one year), construction of two cavities was completed, as well as the leaky check. Currently we are testing the performance, including the alignment, gas selection, photonic fiber selection and testing, and final optical excitation for lasing.

The first cavity is one (1) meter long, has two apertures at the extremes, and a couple of windows on the top (top windows) to facilitate the alignment, as shown in Figure 1. It also has four ¼" Swagelok ports for vacuum, pressure gauge, and methanol purge. One of the side windows is made of ZnSe to allow the CO_2 beam to get in. The window in the opposite side is made of thick polyethylene to allow the THz beam out and block the CO_2. The cavity allows for the installation of a rail to hold the mirrors and the fiber or silicon tube. This first cavity presented some leakage that set the vacuum level to 150 mTorr. The leakage was caused by the top windows and the Swagelok ports, which were not able to hold the vacuum for a long period of time.

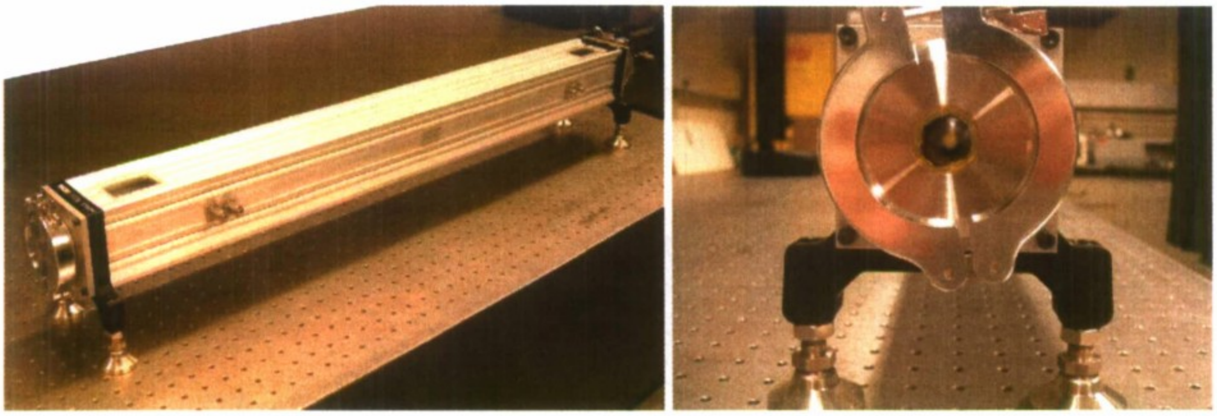

Figure 1. First vacuum cavity. The length is one (1) meter. Detail of the ZnSe window.

A second, shorter vacuum chamber was built in order to address the limitations of the first one. The length is 750 mm and no top windows or vacuum ports were attached. Instead, the windows and ports are built in vacuum tees, which are attached to the both extremes of the cavity (Figure 2).

Figure 2. Second vacuum cavity. The length is 750 mm. The Swagelok port and top windows have been replaced by vacuum tees at both ends of the aluminum profile.

Although this cavity is able to hold a vacuum level of 30 mTorr for an hour or so, there is still some leakage that increases the vacuum level to 100 mTorr. The problem is partially due to the inter-joints, as well as the internal wall. After extended pumping (over 24 hours), especially with heating the device, we expect that a much better vacuum will be achieved.

3. Discussion

The main challenge is to design a fiber in which both the generated THz laser radiation and pump laser radiation can propagate with low losses.

We proposed to fill the fiber with methanol gas at low pressure. The fiber would be terminated by two feedback mirrors at the extremes. The hollow core of the fiber filled with gas would behave as the gain medium and waveguide at the same time. It also works as a laser cavity. The gas will be pumped with a CO_2 laser radiation at 2.54 THz, which provides a theoretical efficiency of 4%. The pump power will be 50 W and the pressure of the methanol inside the fiber must be kept around 100 mTorr.

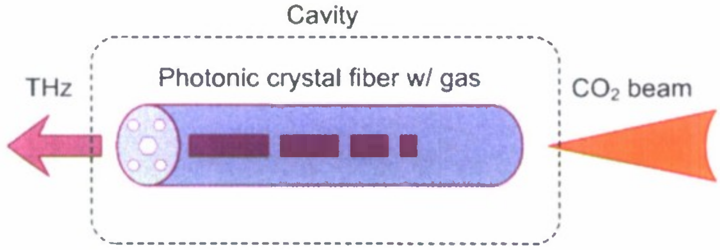

Figure 3. Laser device concept.

Literature research and market research enabled us to find a fiber that could propagate terahertz and visible light. We also contacted Corning[2] to determine if they could help in the development of such a fiber. The results were not successful, so we plan to use a regular silicon tube as a fiber and build a cavity to achieve THz lasing similar to the function of a CO_2 pumped THz laser. The CO_2 pump will be extracted from a THz gas cavity. In that sense, we intend to replicate the operation of the THz gas laser in the cavity with the silicon tube. Once lasing is achieved, it could be possible to repeatedly replace the silicon tube by another fiber or material until we find one that can achieve lasing as a fiber laser.

4. Recommendations

Our following steps are:

- to partner with a company (Corning has been identified and is currently working with us) to design and manufacture a fiber that will meet the requirement of being able to propagate both the pump laser and the THz radiation.
- use of photonic crystal fiber design and non-linear polymer materials to design the fiber.
- replacing the actual cavity by one that can achieve a one (1) mTorr or less vacuum level.

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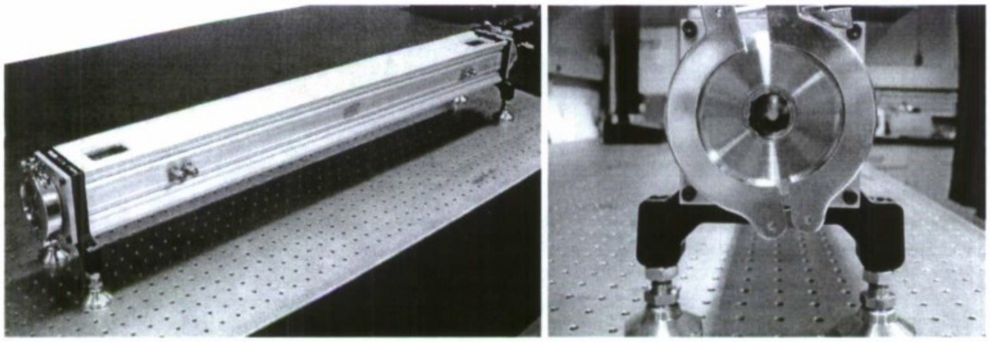

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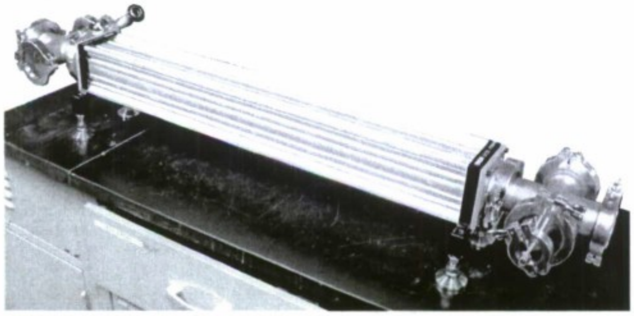

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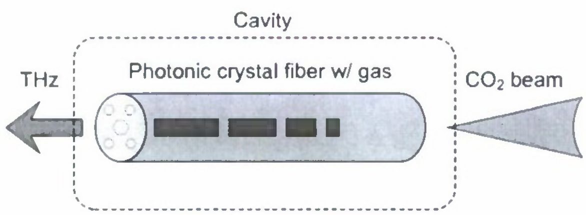

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